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SPECIFICATIONS AND TOLERANCES

for Reference Standards and Field Standard Weights and Measures

2. Specifications and Tolerances for Field Standard Measuring Flasks

NIST Handbook 105-2

1996

Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

2. Specifications and Tolerances for Field Standard Measuring Flasks

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April 1996

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NIST Handbook 105-2
1996

(Supersedes NBS Handbook 105-2)

National Institute of Standards and Technology Handbook 105-2, 1996 Edition
Natl. Inst. Stand. Technol. Handb. 105-2, 1996 Ed., 15 pages (April 1996)
CODEN: NIHAE2

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1996

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

Preface

The 1996 revision of Handbook 105-2 includes the following changes since it was last published in 1971:

1. References to the National Bureau of Standards (NBS) have been replaced by the National Institute of Standards and Technology (NIST).

2. Reference to and incorporation of international standards (such as those of the International Organization for Legal Metrology, OIML) and national industry standards (such as those of the American Society for Testing and Materials, ASTM) have been made where possible.

3. The addition of references to direct the user to publications that will assist with effective use of field standards as described herein.

Additionally, the process for updating the publication has changed to include the following:

1. Conversion of the previous handbook to electronic media to allow future changes to be incorporated in a more timely manner.

2. Organized peer review to ensure incorporation of the latest technology and viewpoints of technical experts.

Note regarding units of measure:
The SI unit of volume is the cubic decimeter (dm^3) or the cubic centimeter (cm^3). The Twelfth General (International) Conference on Weights and Measures redefined the litre [herein spelled liter] as a "special name for the cubic decimeter," but agreed to permit the continuance of the terms liter (L) and milliliter (mL), except in association with measurements of the highest precision. For volumetric glassware, the difference between the old and new meanings of liter is negligible. Therefore, either mL or cm^3 may be marked on flasks and glassware covered in this handbook.

Since commercial applications in the United States use units other than SI or other accepted metric units, this document references other common units in current use.

Acknowledgment:
The previous edition of this Handbook was written by Blayne C. Keysar of NIST in 1971.
Special thanks regarding this updated edition are given to Kelleen Moody, metrologist with the State of Arizona, and to Karl Herken, metrologist with the State of Kansas, for their assistance with review of reference materials, evaluation of comments submitted during peer review, and for typing and editing the document in WordPerfect format. Thanks are also given to numerous metrologists (of both State and industry laboratories) for their technical review of several drafts.

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SPECIFICATIONS AND TOLERANCES FOR REFERENCE STANDARD AND FIELD STANDARD WEIGHTS AND MEASURES

2. Specifications and Tolerances for Field Standards Measuring Flasks

These specifications and tolerances are recommended as minimum requirements for standards used by State and local weights and measures officials in quantity determination of liquid commodities.

Key Words: field standard measuring flasks; flasks; graduated cylinders; volumetric standards; volumetric specifications and tolerances; weights and measures.

INTRODUCTION

Field standard volumetric flasks and graduated cylinders as described herein are intended to be used by weights and measures officials, manufacturers and distributors of liquid products, research and testing laboratories, and others concerned with accurate measurements of the volume of liquids. Use of these volumetric standards at all appropriate levels of manufacture, distribution, and weights and measures inspection will promote accuracy and uniformity in commerce.

1 Scope

1.1 "Field Standard" Classification

This handbook classifies volumetric flasks with graduated necks and graduated cylinders (see Figures 1 through 4) for legal metrology applications as "field standards." Tolerances defined in this handbook must be less than one third of the applicable tolerance when the standard is used to test a package or commodity. Tolerances are intended to permit use of field standards during normal testing operations as standards having nominal values. For specifications and tolerances for glassware used in laboratory applications, where tighter tolerances are needed, see the ASTM references.

1.2 Retroactivity

This handbook applies to new field standard volumetric flasks and graduated cylinders intended for replacement of flasks already in use, or when new flasks are to be acquired as supplementary standards. It does not apply to field standard glass flasks or graduated cylinders already in use.

1.3 Safety Considerations

The accuracy and repeatability of field standards is critically dependent upon cleanliness. Chemicals used in the cleaning process should be evaluated for safety in use and for appropriate disposal methods by reviewing Material Safety Data Sheets (MSDS) .

Volumetric glassware should not be emptied by holding onto the neck alone. The bottom of the flask should always be supported to prevent glassware breakage and possible injury.

2 Reference Documents

2.1 OIML.[1]

2.1.1 Fourth Preliminary Draft, International Document on Measurement of Volume of Liquids, Hierarchy Schemes, December 1987.

2.1.2 International Recommendation No. 43, Standard Graduated Flasks for Verification Officers, 1976.

2.1.3 International Recommendation No. 4, Volumetric Flasks (one mark) in Glass, 1972.

2.2 NIST.[2]

2.2.1 NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, see current edition, published annually.

2.2.2 NIST Handbook 133, Checking the Net Contents of Packaged Goods.

2.2.3 NIST Handbook 145, Handbook for the Quality Assurance of Metrological Measurements, 1986 (or later edition).

2.2.4 NIST LC 1070, Factors for High Precision Conversion, (NBS), 1976.

2.3 ASTM.[3]

2.3.1 E 288-94, Standard Specification for Laboratory Glass Volumetric Flasks, 1994.

2.3.2 E 438-90, Standard Specification for Glasses in Laboratory Apparatus, 1992.

2.3.3 E 542-94, Standard Practice for Calibration of Laboratory Volumetric Apparatus, 1994.

2.3.4 E 694-94, Standard Specification for Laboratory Glass Volumetric Apparatus, 1994.

2.3.5 E 1272-95, Standard Specification for Glass Graduated Cylinders, 1995.

3 Terminology

Borosilicate glass. A glass of a low cubical coefficient of thermal expansion used for most precision laboratory glassware and known by such trade names[4] as Kimax (KG-33) or Pyrex. See ASTM E 438 for Type I glass specifications.

Capacity, contained. The volume of water which the flask contains at the reference temperature when filled to its nominal graduation line and is designated "to contain" or << In >>. The neck graduations of a "to contain" measure represent the volume of liquid in the measure, not the volume of liquid that can be poured from the measure. A "to contain" measure must always be cleaned and dried between successive uses of the measure for purposes of accuracy.

Capacity, delivered. The volume of water which the flask delivers at the reference temperature from the specified graduation line when emptied gradually with a 30 second (± 5 seconds) pour and a 10–second drain while held at a 10° - 15° angle from vertical. These flasks are designated "to deliver" or << Ex >>. If a flask or graduated cylinder is to be used in a wet condition, it must be calibrated "to deliver." The advantage of using a "to deliver" measure is that the measure does not have to be dried between uses.

Capacity, nominal. The nominal capacity of a field standard flask or graduated cylinder is the volume used to designate the flask or cylinder.

Graduation lines. Numbered lines which extend for at least 3/4 of the flask neck or cylinder circumference.

Nominal graduation line. A line extending completely around the flask neck or cylinder

circumference (see 4.4.2) that indicates the nominal capacity and which must be in a contrasting color to the other lines (see 4.5.6).

Soda-lime glass. A glass of medium cubical coefficient of thermal expansion typically used in field standard flasks and graduated cylinders. See ASTM E 438 for Type II glass specifications.

Subdivision graduation lines. Unnumbered intermediate graduation lines between nominal and other graduation lines.

4 Specifications

4.1 Nominal Values

A set of field standard flasks and graduated cylinders comprises a number of flasks. Nominal capacities in the series are chosen in accordance with applications and regulations.

4.1.1 Metric

A set of metric field standard flasks consists of a 50 mL graduated cylinder, a 100 mL graduated cylinder or flask, and one each 250 mL, 500 mL, 1 L, 2 L graduated neck flasks.

4.1.2 Customary (Inch-Pound)

A set of U.S. customary field standard flasks and graduated cylinders consists of a 2 fl oz graduated cylinder, and one each 1 gill, ½ pint, 1 pint, 1 quart, ½ gallon, and 1 gallon graduated neck flasks.

4.2 Reference Temperature

The temperature at which the flask or cylinder is intended to contain or deliver a volume equivalent to its nominal capacity, shall be 20 °C (68°F).

Application note: When a product that is normally refrigerated is being tested, a packager is *given the benefit of doubt* in determining volume, unless temperature corrections are made, due to the cubical thermal coefficient of expansion for the glass and for the product; the extent is dependent on whether product is tested at its specified reference temperature, its storage temperature or at a normal indoor environment (i.e., 20 °C.)

4.3 Material and Annealing

A field standard flask or graduated cylinder shall be made of transparent, well annealed clear glass with suitable thermal and chemical properties (such as ASTM Type II, soda-lime or Type I, borosilicate glass). The flask shall be free from chips, cracks, stones, and other visible defects that detract from the appearance or use of the flask. It is particularly important that the graduated portion of the flask or cylinder be free from obvious defects.

4.4 Physical Properties

4.4.1 General

The design shall conform to the general configuration shown in the Figures 1-4. The inscriptions and graduations shall be placed in the same relationship to each other and to the position on the flasks as shown.

4.4.2 Cylindrical Design

The neck and body of flasks and graduated cylinders must be cylindrical. Any cross section taken in a plane perpendicular to the vertical axis shall be circular.

4.4.3 Construction

The shape of a field standard flask or graduated cylinder shall permit complete emptying and thorough cleaning.

4.4.4 Base

A standard graduated flask must maintain a stable vertical position without rocking when placed with its base on a flat level surface. Each flask shall be designed with an attached base that is perpendicular to the vertical axis for stability. (A hexagonal base is typically used for maximum stability, but the 1-gallon flask is often designed in such a way that eliminates the need for a base.)

4.4.5 Neck

The neck of the flask must be cylindrical. The top edge of the neck shall have a smooth finish and a small flange. The height of the graduated portion of a graduated cylinder shall be at least five times the inside diameter.

4.5 Lines, Graduations and Inscriptions

4.5.1 Line Widths

Graduation and subdivision lines shall be distinct, permanent and of uniform thickness not to exceed 0.3 mm.

4.5.2 Line Orientation

Graduation lines shall be perpendicular to the vertical axis of the base of the flask.

4.5.3 Line Construction

Graduation lines shall be applied by one of the following methods: etched and filled with a permanent pigment; application of a stain fixed into the glass without etching; or application of an enamel fused onto the glass without etching.

4.5.4 Graduation Pattern

There should be no evidence of irregular spacing between graduation lines. The graduation lines shall extend completely around the neck. Due to the difficulty in extending stained or enameled lines completely around the neck, a gap of 4 mm at the closure, or meeting point, is permitted. This gap must be approximately 90° from the line of vision when the flask is viewed from the front so as not to interfere with reading a meniscus (see Figures).

4.5.5 Subdivision Lines

Subdivision lines shall be uniform and extend at least halfway around the neck.

4.5.6 Line Color

If a pigment or enamel is used for graduation lines, the nominal volume line shall be of a contrasting color.

4.5.7 Graduation and Nominal Graduation Lines

Graduation lines on flasks with graduated necks shall be marked above and below the nominal line as shown in Volumetric Scale Range in Table 1.

Graduation lines on graduated cylinders shall only be marked beneath the nominal line and shall be marked with Numbered and Minimum Graduations as shown in Table 1.

Subdivision lines on graduated cylinders shall be omitted between the base and the first main graduated line. This will eliminate reading near the base where it is difficult to read and of questionable accuracy. (Striation often occurs in the glass in this area during manufacture when the base is joined to the cylindrical portion.)

4.5.8 Graduation and Nominal Graduation Inscriptions

Each nominal capacity line shall be labeled with the appropriate volume and units. The numbers and letters indicating nominal capacity and main graduation capacities shall be placed immediately above the line to which they refer (see figures for examples).

4.5.9 Scale Divisions, Metric

The scale divisions on a metric graduated cylinder shall be divided into milliliters, and labeling shall so indicate with the appropriate abbreviation: mL. Each subdivision shall be 1 mL; at each 10 mL there shall be a main graduation line.

4.5.10 Scale Divisions, Customary

The scale divisions on a U.S. customary graduated cylinder shall be divided into fluid drams, and labeling shall so indicate with the appropriate abbreviation: fl dr. Each subdivision shall be ½ fl dr; at each 2 fl dr there shall be a main graduation line.

4.5.11 Identification

Each field standard flask or graduated cylinder shall be permanently and legibly marked with the following:

1) the manufacturer's name or trademark;
2) serial or identification number;
3) clear identification of "to deliver" or "to contain" use ("to deliver" flasks with a proper *wet down* are typically used for commodity inspection);
4) nominal capacity and appropriate units;
5) reference temperature for calibration; and
6) drain time (e.g., 10 s).

On U.S. customary standard glassware all letters except unit abbreviations are to be in upper case. (See Figures.)

5 Tolerances (Maximum Permissible Error)

The difference between the actual volume and the indicated volume at the prescribed reference temperature (20 °C) shall not be greater than that shown for Tolerance at Nominal or Partial Capacity in Table 1. The actual value shall agree with the nominal value within plus or minus the stated tolerances.

6 Verification Requirements

6.1 Legal Requirements

When field standard flasks and graduated cylinders are used for commercial applications they must be inspected and verified by a NIST accredited laboratory, using appropriate test methods, with valid calibration or inspection certificates provided.

6.2 Traceability

Field standards shall be tested by an accredited laboratory. Field standards used for legal metrology are typically traceable to national standards for length, mass, and capacity, through standards which were supplied to the State metrology laboratories by NIST in the New State Standards Program (1965). Continued traceability of State standards is ensured through NIST laboratory accreditation.

6.3 Calibration Reports

Acceptable accuracy and traceability to national or international standards shall be documented in a calibration report using accepted test methods. Calibration values, uncertainty, and tolerance status must be noted on the calibration report for the user's evaluation.

6.4 Initial & Periodic Verification

Field standard flasks and graduated cylinders must undergo initial verification for conformance to these specifications and tolerances. Field standards must be inspected or verified periodically as prescribed by regulation; the frequency of periodic inspection and/or verification depends upon usage but should not exceed 10 years. Glass flasks and graduated cylinders generally do not change capacity values during this period of time unless damaged. Comparisons against

other standards should be performed occasionally to detect those standards in need of recalibration.

7 Test Methods & References

Initial verification to determine whether field standard flasks and graduated cylinders meet applicable tolerances is performed by calibration using accepted volume transfer or gravimetric calibration procedures. The uncertainty of the test method must be less than one-third the applicable tolerances. If commercial measurements are to be made, there may be additional test/verification requirements (dependent on the jurisdiction in which the field standards will be used). Referenced methods are as follows:

7.1 NIST Handbook 145, SOP 13

SOP 13, Recommended Standard Operating Procedure for Calibration of Volumetric Ware, Gravimetric Method.

7.2 NIST Handbook 145, SOP 14

SOP 14, Recommended Standard Operating Procedure for Gravimetric Calibration of Volumetric Ware Using an Electronic Balance.

7.3 NIST Handbook 145, SOP 16

SOP 16, Recommended Standard Operating Procedure for Calibration of Measuring Flasks, Volume Transfer Method.

7.4 ASTM E 542-94

Standard Practice for Calibration of Laboratory Volumetric Apparatus, 1994.

7.5 OIML IR No. 43, Appendix A

International Recommendation No. 43, Standard Graduated Flasks for Verification Officers, 1976. Appendix A contains a procedure (without necessary equations, which are given in the other references) for gravimetric calibration of glass flasks used for verification officers.

8 Uncertainties

8.1 Legal Applications

Uncertainties of the calibration must be evaluated according to the ISO Guide for the Expression of Uncertainties in Measurements,[5] 1993, to ensure that the required three to one accuracy ratio of NIST Handbook 44 is maintained.

8.2 Sources of Variation

For microliter volumes measured without a meniscus, the largest source of uncertainty and potential bias is often evaporation. For larger volumes such as those listed in this handbook, the largest sources of uncertainty are inaccurate reading of the meniscus (see NIST Handbook 145, Good Measurement Practice, GMP 3), cleanliness of the container, and proper technique when emptying the flask or cylinder. A 30 s (± 5 s) pour followed by a 10 s drain, with the measure held at a 10° - 15° angle from vertical, is required during calibration and application. The uncertainties reported by the laboratory do not reflect the uncertainty in field applications; field application uncertainties include the same type of factors and are additive to those reported by the laboratory.

9 Abbreviations

Cubic Centimeter ..... cc or cm^3
Cubic Decimeter ..... dm^3
Cubic Millimeter ..... mm^3
Fluid Dram ..... fl dr
Fluid Ounce ..... fl oz
Liter L
Milliliter ..... mL
Pint ..... pt
Gallon ..... gal

Table 1. Tolerances (maximum permissible error) for flasks and cylinders

Capacity at 20 °C mL	Tolerance at Nominal Capacity ± mL	Tolerance at Partial Capacity ± mL	Volumetric Scale Range (above and below nominal) mL	Numbering mL	Minimum Graduations (subdivisions) mL
50 cylinder	0.30	0.30	See 4.5.7	10.00	1.00
100 flask	0.20	0.06	4.00	2.00	0.50
250	0.30	0.10	6.00	5.00	0.50
500	0.50	0.15	10.00	5.00	1.00
1000	0.80	0.22	20.00	5.00 or 10.00	1.00
2000	1.20	0.33	30.00	10.00	2.00
Capacity at 20 °C (units)	Tolerance at Nominal Capacity ± mL	Tolerance at Partial Capacity ± mL	Volumetric Scale Range (above and below nominal) fl dr	Numbering fl dr	Minimum Graduations (subdivisions) fl dr
2 fl oz (59 mL) cylinder	0.30	0.30	See 4.5.7	2.00	0.50
1 Gill flask (118 mL)	0.20	0.10	0.50	0.50	0.25
½ pt (236 mL)	0.30	0.10	1.00	0.50	0.25
1 pt (473 mL)	0.40	0.15	2.00	1.00	0.50
1 Quart (946 mL)	0.70	0.30	4.00	2.00	1.00
½ gal (1,892 mL)	1.00	0.30	6.00	2.00	1.00
1 gal (3,785 mL)	1.20	0.30	8.00	2.00	1.00

For volumetric measures less than 50 mL, full capacity tolerances do not apply. For these volumetric measures, apply 0.10 mL to individual graduations. For a capacity intermediate between two capacities listed above, the tolerances prescribed for the lower capacity shall be applied. For volumes greater than 3,785 mL (1 gallon) apply ± 0.02 percent of nominal capacity for tolerances at full capacity and ± 0.3 percent of the minimum graduation for tolerances for individual graduations.

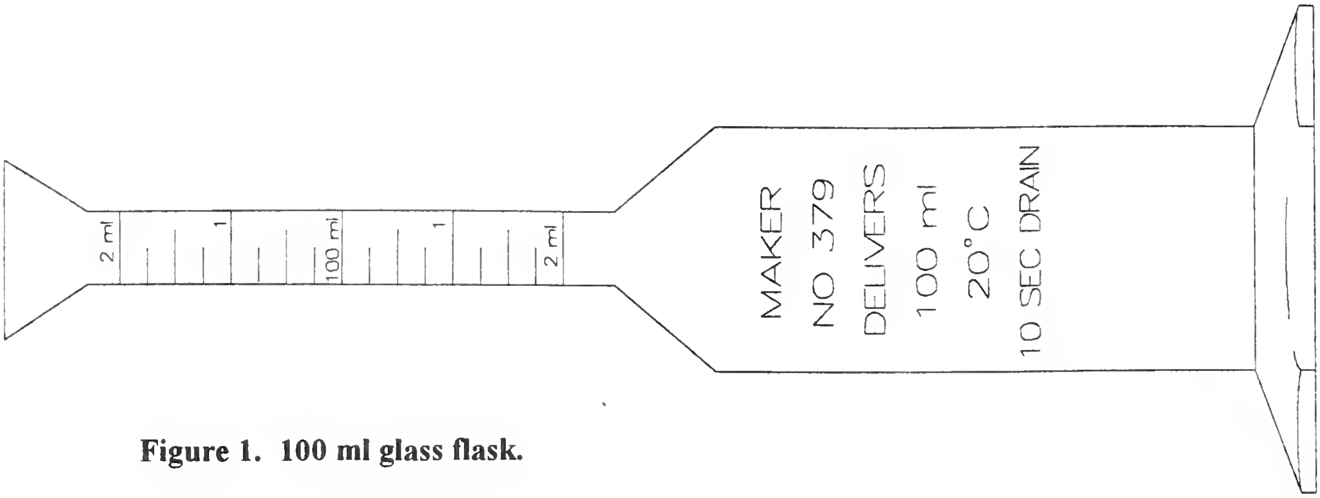

FIGURE 1

Figure 1. 100 ml glass flask.

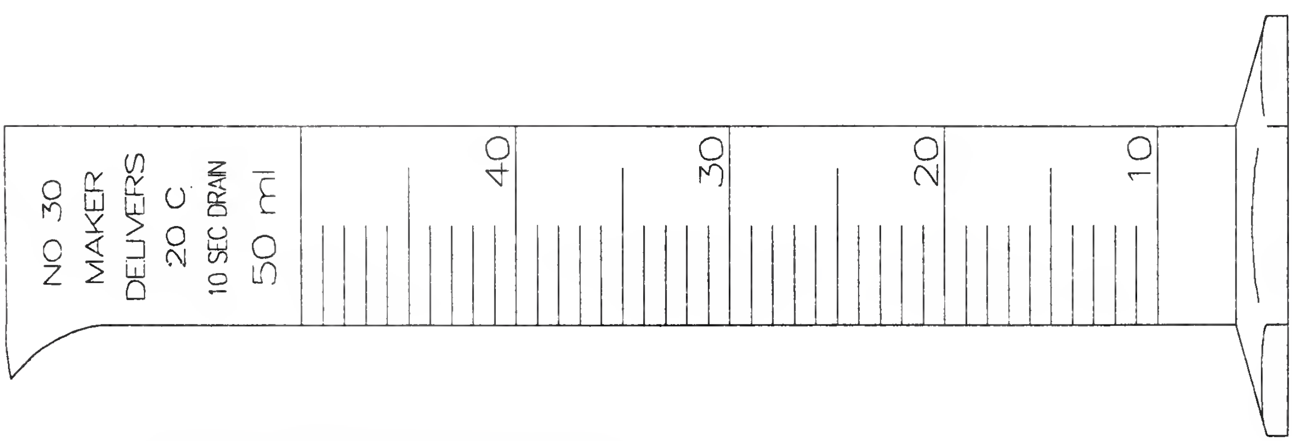

FIGURE 2

Figure 2. 50 ml graduated cylinder.

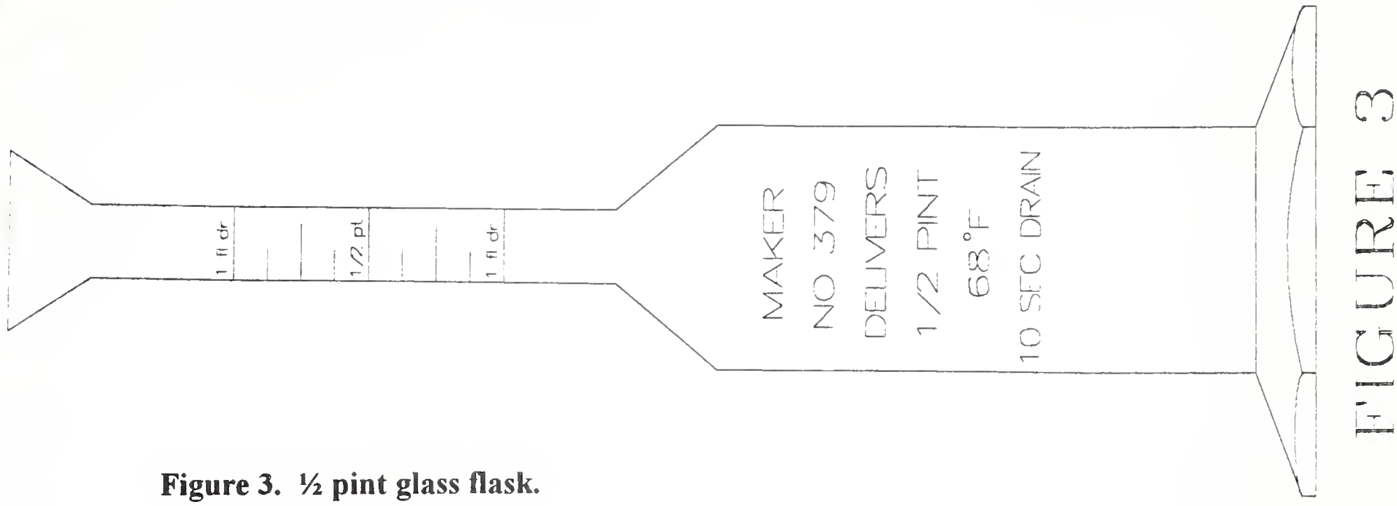

Figure 3. ½ pint glass flask.

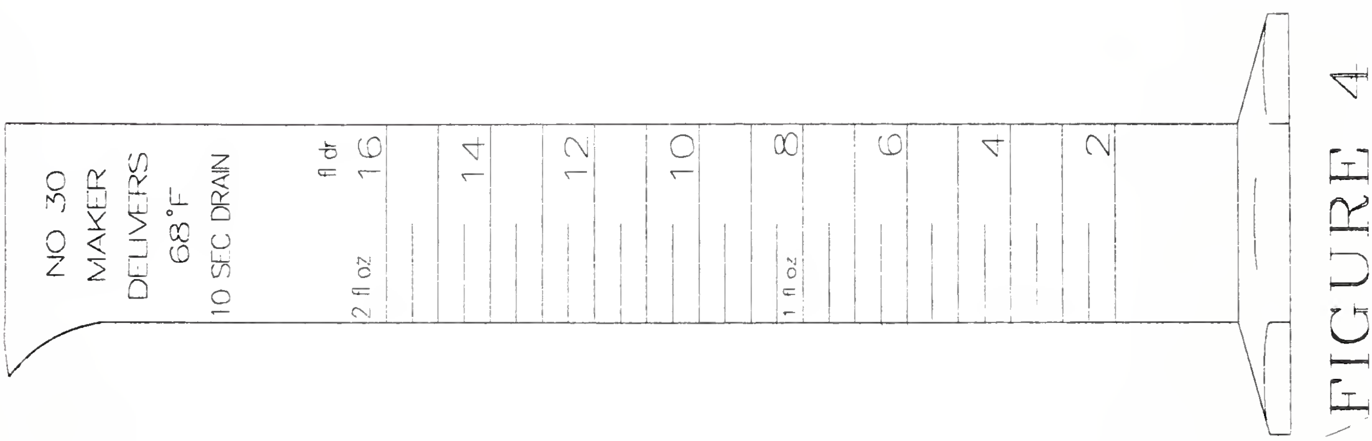

Figure 4. 2 fl oz graduated cylinder.

Notes

1. OIML, L'Organisation Internationale Metrologie Legale, Bureau International De Metrologie Legale, 11 Rue Turgot, 75009 Paris, France.

2. NIST, National Institute of Standards and Technology, Gaithersburg, MD 20899.

3. ASTM, American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

4. Trade names as used in this handbook do not imply recommendation or endorsement by the National Institute of Standards and Technology (NIST).

5. ISO, International Organization for Standardization, Geneva, Switzerland.

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